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A Perceptional Investigation into the Adoption of Timber Bridges

The Role of New Technology Adoption in the Timber Bridge Market: Special Project Fiscal Year 1992

PREFACE

This publication is a technology transfer effort by the USDA Forest Service, Timber Bridge Information Resource Center, in cooperation with the Center for Forest Products Marketing, Department of Wood Science and Forest Products, at Virginia Polytechnic Institute and State University, under a grant from the USDA Forest Service.

This publication is Part II of a five-part marketing analysis of Timber Bridges. It examines the perception of bridge-building materials in regard to four distinct groups of decision makers with five geographic regions of the United States. Several attributes of Parts 1, 2, 3, & 4 were rated by various highway officials and statistically evaluated. Marketing strategies are suggested for the timber bridge industry.

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Other publications in this five-part series are:

Factors Influencing the Adoption of Timber Bridges, NA-TP-02-95 (Part I)
A Hierarchical Analysis of Bridge Decision Makers, NA-TP-04-95 (Part III)
Marketing Practices in the Timber Bridge Industry: 1993, NA-TP-05-95 (Part IV)
A Strategic Evaluation of Factors Affecting the Adoption of Timber Bridges, NA-TP-06-95 (Part V)

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Timber Bridge Information Resource Center

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The Role of New Technology Adoption in the Timber Bridge Market: Special Project Fiscal Year 1992

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A Perceptional Investigation into the Adoption of Timber Bridges

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Abstract

Perceptions of major bridge materials by four distinct groups of decision makers were investigated within five geographic regions of the United States. Timber was rated lowest in perceived performance within each group and region. Timber was compared to prestressed concrete, steel, and reinforced concrete on eight pre-selected attributes. Timber was rated lowest on the attributes of *Low maintenance, Easy to design, Long life, and High strength.* Only on the attribute of *Easy to construct* did timber rate above reinforced concrete. In all cases, timber never rated higher than prestressed concrete on any attribute. Highway officials who have participated in the Timber Bridge Initiative rated timber as a bridge material statistically higher in overall performance than those highway officials who have not participated in the program. Marketing strategies are suggested for the timber bridge industry.

Introduction

Traditional market research investigates the purchaser of a product as its consumer. However, many products require design decisions where engineers or other decision makers influence product specification. This has been demonstrated recently with the use of timber in modern bridges. Unless bridge engineers and highway officials are willing to utilize timber in their designs, no amount of promotion to the contractor (purchaser) will increase the use of timber for bridge construction.

The need for bridge replacement has been well documented (Brungraber et al. 1987, Cheney 1986, USDA 1989, USDOT 1989). Timber bridges currently represent less than eight percent of all U.S. bridges (FHWA 1992). Other bridge-building materials include prestressed concrete (15%), reinforced concrete (40%), and steel (37%). Since 1982, prestressed concrete and reinforced concrete have been used in more than 70 percent of bridge replacements; timber represents less than 6 percent. This suggests that negative perceptions of timber may exist, and it is necessary to understand how engineers perceive timber on various factors in comparison with other bridge materials. Judgmental data, in the form of perceptions or preferences, may indicate the reasons for present patterns and provide insights into future patterns of competition (Day et al. 1979). This knowledge can serve as the basis for strategic planning.

All too often, the evaluation of strengths and weaknesses of competing products is limited to tangible characteristics such as price or physical attributes, disregarding intangibles such as consumer perceptions and attitudes (Dickson 1974). However, it is these perceptions that often determine belief about a material, which formulate an attitude and influence the design decision. In marketing, one must be concerned with perceptions as much as reality (Hiam and Schewe 1992). It is not reality that drives our behavior, but our perception of reality.

Although the importance of perceptional variables in determining purchase behavior is established in marketing literature (Green and Carmone 1970, Johnson, 1971, Lehmann and O'Shaughnessy 1974), little information is available concerning perceptions of and attitudes toward finished products made of wood. Cooper and Kalafatis (1984) investigated various species and end-use products. Blomgren (1965) studied the psychological image of wood. However, to date, little quantitative marketing research has been done involving design engineers' perceptions of various building products or how timber is perceived by various highway officials as a bridge material.

Clapp (1990) and Luppold (1990) conducted qualitative studies on timber perceptions in the Northwest and South, respectively. Both concluded that timber was not perceived well as a bridge material. Dunker and Rabbat (1992) conducted an extensive analysis of the National Bridge Inventory to compare the performance of prestressed concrete and other major bridge materials since 1950. They concluded that prestressed concrete has out performed all other materials in the past forty years, with timber being the poorest performing material.

Rosenberg et al. (1990) state that the development of many new wood products has been driven by resource availability, cost, and technology — not customer needs. Yet this is in contrast with the marketing concept where the customer is the focal point of product development. In today's marketplace, understanding the needs of the customers and potential customers is becoming more essential to success (Cooper 1988, Porter 1980). This study seeks to improve understanding of highway officials as customers in the bridge material decision.

Objective

The objective of this study was to determine perceptions of timber as a rural bridge material. Specifically, to analyze this objective, the following propositions were investigated:

Proposition 1. Decision makers perceive timber to be lower in overall performance than competing rural bridge materials (prestressed concrete, steel, reinforced concrete).

The decline in the use of timber during the twentieth century indicates that highway officials do not consider timber to be of the same performance or standards as other bridge materials.

Proposition 2. Perceptions of the overall performance of timber as a rural bridge material differ by decision-maker type (State DOT, private consultant, or local highway official).

The greatest use of timber is by highway officials at the local unit of government. Over 80% of timber bridges are located on low-volume rural roads. This indicates that local highway officials may perceive timber to be a better performing material than other decision makers do.

Proposition 3. Perceptions of the overall performance of timber as a rural bridge material differ by geographic region.

Differences exist between timber bridge usage by geographic region. The greatest timber use in bridges is in the deep South and the Midwest United States. The lowest number of timber bridges is in the Mid-Atlantic and Northeastern United States.

Proposition 4. Perceptions of the overall performance of timber differ based on past usage in bridges and previous educational exposure to timber design.

It is believed that those highway officials who have used timber in the past five years, or those who have had a timber engineering design course, would perceive timber to perform better than would those individuals who have not used timber or who are not trained in design with timber.

Proposition 5. Timber Bridge Initiative participants' perceptions of the overall performance of timber are better than those of individuals who have not participated in the program.

Efforts by the Timber Bridge Initiative and research institutions are aimed at educating the highway official on modern timber bridges. It is believed that by providing incentives to use timber and design assistance/education, the perception of highway officials will improve in regard to the use of timber as a bridge-building material.

Methods

Sample

A stratified sample of bridge engineers across five distinct geographic regions and four decision-making groups was used. Engineers were segmented into three groups: State Department of Transportation (DOT) engineers, private consulting engineers, and local highway officials. These groups are most influential in the bridge material decision because of their involvement in the allocation of bridge replacement funds. In addition, state/local authorities are responsible for 90% of rural bridge maintenance and replacement decisions (USDA 1989). Individuals who have recently participated in the Timber Bridge Initiative (TBI 1989) were compared with other engineers to identify differences that may exist between adopters of new bridge designs and non-adopters.

To determine if differences exist between geographic regions, five distinct geographic segments were identified. These regions were: Northwest, South, Mid-Atlantic, Northeast, and Midwest (Figure 1). These five areas accounted for over 70% of bridges replaced since 1982 (FHWA 1992) and include 28 states. Market segmentation is often used to identify distinct customer groups that have homogeneous needs (Wind 1978). This allows tailoring the marketing mix for particular segments and leads to better planning and use of marketing resources (Kotler 1988).

Decision Makers

State Department of Transportation Engineers (DOT) - Highway departments in 28 states were contacted by letter requesting a list of engineers involved in rural bridge design, replacement, or maintenance decisions. A random sample consisting of 401 state bridge engineers was selected from this group. The population was stratified to allow each geographic region to be sampled with approximately 80 Department of Transportation engineers.

Private Consulting Engineers - A list of private consultants was requested from the state Department of Transportation in the selected states. This was supplemented by firms listed in the American Consulting Engineers Council Directory (1992-1993). A stratified random sample of 419 private consultants was used for the study.

Local Highway Officials - Most states have an engineer or appointed official at a county/local level that is responsible for routine decisions on maintenance and replacement of rural bridges. Because the emphasis of this study is on rural bridge replacement, a stratified random sample of 406 officials was obtained from directories of local highway officials in the 28 states.

Timber Bridge Initiative Participants - In 1989, the U.S. Congress funded the National Timber Bridge Initiative to improve rural transportation and local economies by utilizing wood for bridge construction. Over 272 demonstration bridges in 48 states have been funded under this program as of 1993 (USDA 1993). To determine if differences exist between bridge decision makers and those involved with innovative timber bridge design, an additional sample of 104 participants from the TBI in the selected 28 states was included in the study.

Geographic Regions - In order to understand why adoption of bridge materials varied between regions of the United States, five discrete geographic areas were utilized for this study. These regions were chosen because of different timber bridge usage, different bridge material selection protocols, and different timber resources. To establish a representative sample of the various engineering groups, each region was sampled with approximately 240 decision makers or 80 at each decision-making level. As a separate group, an additional 104 highway officials who were involved in TBI demonstration bridges were sampled from the 28 states.

Data Collection

A mail questionnaire was used for primary data collection. A mail survey is considered an efficient and cost-effective way of securing data from a wide geographic base. The questionnaire consisted of three primary areas:

- The first area used rating scales to collect data concerning overall bridge material performance and the engineers' past experiences with various bridge materials. This information identified exactly how timber is perceived by engineers and provided a basis for the development of marketing strategies.

- The second area of the questionnaire used rating questions to collect data concerning how timber compares with prestressed concrete, steel, and reinforced concrete on eight pre-selected attributes. These data will assist in addressing where timber must improve performance characteristics.

- The third area consisted of multichotomous questions to gather information about the respondents. In particular, individuals were asked about past exposure to timber engineering.

The questionnaire was reviewed by knowledgeable civil engineers and university personnel to test its face validity, clarity, and ensure that no important bridge material selection factor was overlooked. A pretest was then conducted with bridge engineers in the various decision-making groups in Virginia, Wisconsin, and Minnesota. The responses from this pretest were used to clarify question wording and to revise the set of material attributes and factors in the decision-making process.

A disguised questionnaire with a cover letter explaining the purpose of the study was mailed to 1,330 engineers in April of 1993. No correspondence stated that the study was being conducted by the Department of Wood Science at Virginia Tech, because it was felt that this would bias some respondents' answers or have a negative effect on the response rate. In order to increase response rates, a reminder postcard was sent two weeks after the initial mailing. Four weeks following the initial mailing, a second questionnaire was mailed to non-respondents with a cover letter requesting participation. A second reminder postcard was sent two weeks after the mailing of the second questionnaire. A total of 848 surveys were returned, 751 which were usable, resulting in an adjusted response rate of 61%. Non-usable responses indicated that the decision maker was not involved with bridges or the private consulting firm was no longer in business.

Non-Response - In order to test for non-response bias, 50 non-respondents were contacted by telephone and asked to answer selected questions. These individuals represented the three primary decision-making groups. They were asked questions concerning material preference, ratings of important bridge material factors, timber design education, and job duties.

Multivariate Analysis of Variance (MANOVA) was utilized to determine if significant differences existed between respondents and non-respondents on the selected parameters. In no case could the hypothesis of no difference between respondents and non-respondents be rejected ($\propto$ = .05). Since this study is concerned with timber perceptions, Analysis of Variance (ANOVA) was used to determine if respondents and non-respondents differed. Again, no significant difference (at a $\propto$ = .05) could be determined. These results suggest that non-response bias was not a problem and that respondents represented their respective populations.

Results and Discussion

Data Analysis

Analysis of data began with one-way tabulations to identify coding errors, item non-response, locate outliers, and calculate summary statistics. Multivariate Analysis of Variance (MANOVA) was used to test significant differences between bridge materials, decision-maker groups, and geographic regions. For comparison purposes, factor analysis was utilized to group material attributes into smaller homogeneous units.

Respondents

Forty percent of the respondents were from state DOT offices, 30 percent were classified as private consultants, and 30 percent were local or county highway officials. Forty-four percent classified themselves as design engineers, 17 percent reviewed design plans, 17 percent were responsible for maintenance of bridges, and 22 percent were involved in administration or other activities. Nearly 70 percent of highway officials said their state had standard bridge plans, but only one-third of these said the plans included designs for timber.

Highway officials were asked to state what materials they had used in the past five years in bridge design or replacement. Eighty-four percent of responding officials had used prestressed concrete, 79 percent had utilized reinforced concrete, 68 percent had employed steel in bridges, and 46 percent had experience with timber in bridges. Approximately 40 percent of the respondents had a formal course in timber design, with one-third saying it was mandatory. Fifty-four percent of the respondents indicated they were aware of the recent changes in timber design, with one-half saying these changes have improved their impression of timber as a bridge material.

Overall Performance

To determine if differences existed in the perceived overall performance of different bridge materials, several propositions were posed for analysis. The following section describes each proposition and the result.

Proposition 1. Decision makers perceive timber to be lower in overall performance than competing rural bridge materials (prestressed concrete, steel, reinforced concrete).

Utilizing a Multivariate Analysis of Variance (MANOVA), perceptions of timber were shown to differ by decision-making level and geographic region. Timber was rated lowest by all groups and regions (Table 1). The results indicate that this perception of timber is uniform across decision-making level by geographic region. Timber was the only material to do this.

Prestressed concrete was rated highest, followed by reinforced concrete, steel, and timber. This was uniform by decision group and geographic region. This finding agrees with conclusions drawn by Dunker and Rabbat (1992) concerning the actual performance of bridges as reported in the National Bridge Inventory database.

Proposition 2. Perceptions of the overall performance of timber as a rural bridge material differ by decision-maker type (State DOT, private consultant, or local highway official).

Timber was rated last in performance by each level of decision maker (Table 1). However, significant differences did exist by decision group. Local highway officials, followed by private consultants, rated timber the highest in overall performance. State DOT engineers rated timber the poorest performing bridge material (Figure 2).

Proposition 3. Perceptions of the overall performance of timber as a rural bridge material differ by geographic region.

Significant differences in the perception of timber as a rural bridge material existed by region at a .05 significance level. The Northeast and Midwest regions' decision makers rated timber higher as a bridge material than the other regions. The Mid-Atlantic region rated timber poorest in performance (Table 1).

Although the South has the highest number of timber bridges, decision makers in this region perceived timber to be the poorest performing bridge material. Results from open-ended questions indicate that high decay rates and maintenance requirements are the primary reasons for this perception. Personal interviews in Mississippi indicated that numerous timber bridges are being built without engineering design. This may be one reason for poorer performance of timber bridges in the South.

Proposition 4. Perceptions of the overall performance of timber differ based on past usage in bridges and previous educational exposure to timber design.

To analyze this proposition, engineers who have worked with timber in the past five years were compared with those who have not used timber in bridges or bridge design. Officials who have had a course on timber design during their professional training were compared with those who have not been exposed to timber.

Respondents who have utilized timber in the past five years felt significantly ($p < .01$) better about its overall performance than those who have not used timber. However, there was no difference ($p = .91$) in those individuals who have had a course in timber design during their professional career, to those who have not.

These results indicate that people who have tried timber recently feel better about its performance and that negative perceptions may exist by those who have not tried timber in the past five years. Unfortunately, those individuals who have had at least one course in timber design, feel no differently than those who haven't had a timber design course. This contradicts a current belief that negative perceptions exist because engineers are not trained in timber design. It may also indicate that more than one course in timber design is needed to improve the engineer's perception of timber.

There was no significant difference with the education ($p = .10$) or age ($p = .22$) of highway officials in their perception of timber as a bridge material.

Proposition 5. Timber Bridge Initiative participants' perceptions of the overall performance of timber are better than those of individuals who have not participated in the program.

Timber Bridge Initiative participants perceived timber to be a better performing material than did the other decision-making groups ($p < .01$). This may not be surprising since many of the TBI participants were local officials who rated timber higher than did the state or private engineers. It also supports the theory that individuals who have utilized timber in recent years do perceive it to be better than highway officials who have not used timber in design.

Material Attributes

Every product can be viewed as possessing a collection of characteristics or attributes that impact its commercial success. These characteristics may be physical and measurable — such as modulus of elasticity, market-related as in the case of price, or more nebulous characteristics such as quality or value (Trinka et al. 1992). A thorough understanding of these factors will help place timber better in the bridge marketplace. By identifying how its product compares with competitive products on these attributes, a manufacturer can better address the requirements of its customer.

Eight important attributes were identified in the bridge material choice decision by civil engineers across the United States. These attributes were: *Low maintenance, pleasing aesthetics, environmentally safe, low cost, easy to design, easy to construct, long life, and high strength* (Table 2). On all attributes except *easy to construct*, timber was rated last or second to last. Prestressed concrete and reinforced concrete were the top rated materials on all of the attributes except *easy to construct and high strength* (Figure 3).

Factor Analysis of Material Attributes

Hair et al. (1992) states that factor analysis can be utilized to examine the underlying patterns or relationships for a large number of variables and to determine whether or not the information can be condensed or summarized in a smaller set of factors or components. Principal component factor analysis is used when the objective is to summarize most of the original information (variance) in a minimum number of factors for prediction purposes.

Employing a principal components factor analysis to the eight attributes for each bridge material type, two factors with an eigenvalue greater than 1 resulted. This criterion, according to Stevens (1986), is probably the most widely used in determining the number of factors to be retained. Each attribute's loadings (correlations) on the respective factor exceeded 50 percent, which according to Dillon and Goldstein (1984), is the test for *practical significance*. With each of the four separate factor analyses, the

same 5 variables loaded on factor 1, and the remaining 3 variables loaded on factor 2 (Table 3). A varimax rotation was employed to assist in the interpretation of variables as suggested by Hair et al (1992). The first factor was grouped according to physical characteristics (*long life, high strength, low maintenance, environmentally safe, and pleasing aesthetics*) while the second factor was design decision criteria (*easy to design, low cost, and easy to construct).*

The reliability of the two factors was analyzed using Cronbach's alpha. The cutoff point to measure if a factor was internally consistent (reliable) was .60 (Bogozzi and Youjae 1988, Peter 1979). For each material, the reliability exceeded this minimum, which indicates that the dimensions created by the factor analysis were internally consistent (Table 3).

Following the factor analysis, computation of factor scores is possible to obtain composite observations on each factor. Hair et al. (1992) states that factor scores have the advantage of representing a composite of all variables loading on the factor, whereas surrogate variables represent only a single variable. A simple method to compute factor scores is to add up the raw scores for any given individual's loading on a factor (Comrey and Lee 1992). Mean factor scores were then calculated for each material type: prestressed concrete, steel, timber, and reinforced concrete.

Material Dimensions

Timber was rated lower on the *physical characteristics* dimension and rated only equal with steel on the *design criteria* dimension (Fig. 4). Timber was rated lowest by state DOT and private engineers on each dimension. Local highway officials rated timber higher on *design criteria*, and those who have participated in the recent Timber Bridge Initiative (TBI) rated timber higher on p*hysical characteristics* (Fig. 5).

Geographically, timber was rated higher on *design criteria* in the South and lower in the Mid-Atlantic states. On *physical characteristics* it was rated higher in the Midwest and lower in the South (Fig. 6). Since the South and Mid-Atlantic regions had the lowest overall perception of timber, this may indicate that the *physical characteristics* of the product dominate when a perception is developed. It would also indicate that it is the primary dimension in which manufacturers need to address their efforts to improve timber as a bridge material.

Highway officials who had utilized timber within the past five years rated timber statistically higher than those individuals who have not used timber on both dimensions ($p < .01$). Previous educational training in timber design had little effect on their overall ratings of the two dimensions ($p < .35, p < .42$).

Those officials who have participated in the Timber Bridge Initiative rated *physical characteristics* higher ($p < .01$) than highway officials as a group. These results are supported by those individuals who said they were aware of the recent changes in timber bridge design ($p = .04$), or have attended a timber bridge conference ($p < .01$). They felt significantly better about the *physical characteristics* than those who were not aware of changes.

There was no significant difference between these groups and other officials on the dimension of *design*. These improvements in perceptions on *physical characteristics* may be attributed to recent educational activities of the Timber Bridge Initiative.

Criteria Important in Choosing a Bridge Material

Respondents were asked to rate the importance of certain factors in their choice of a bridge material. The number one factor was other highway officials (peers). Opinion leaders will play a very important role in the transfer of timber bridge technology. Identification of these individuals will assist in continued adoption of modern timber bridges. This was followed by government research, journal articles about materials, and seminars sponsored by material suppliers.

All of these can be classified as *educational activities*. Education may reduce the risk that highway officials may perceive in trying this new technology. Risk is an important factor in the design decision. Not only is safety of the material an issue, but the reputation and professional license of the engineer may be in question if a product fails. Every effort needs to be made in reducing the risk the highway official perceives to exist when trying a modern timber bridge.

Marketing practices reportedly had little influence on their choice of bridge materials. The lowest rated factors were advertisements in magazines, personal calls by sales representatives, unsolicited sales literature, and trade shows or conventions. Although marketing practices were rated low, highway officials may have been reluctant to indicate that marketing played an important role in the source of information for their decisions.

Officials were asked open-ended questions concerning the best locations for timber bridges. Repeatedly the response was *low volume, short span*, and in *aesthetic area*s. However, timber was not rated the highest on this latter bridge attribute.

Conclusion

This study sought to determine exactly how engineers and highway officials perceived timber on certain important attributes. Timber was perceived to be the poorest performing material for bridge applications compared to prestressed concrete, steel, and reinforced concrete. The only attributes it rated well on were *easy to construct* and *pleasing aesthetics*. However, prestressed and reinforced concrete rated higher than timber on the attribute of *pleasing aesthetics*.

Respondents did perceive timber to be different by decision group. Local officials rated timber better than did private consultants and state DOT engineers. Timber rated higher in the Northeast and Midwest regions of the United States. The education, age, and training of the decision maker had little effect on their perceptions of timber. The major factor was past usage of timber, suggesting that perceptions of timber will improve with use of new designs. This was also supported by the Timber Bridge Initiative participants who rated timber higher in perceived performance and the attribute dimension, *physical characteristics*.

Timber design engineers need to address the requirements of reducing maintenance and increasing the life span of timber bridges to gain wider acceptance. Designs must also be aimed at reducing total bridge costs. Experts in wood treating must address why timber in bridge use is not lasting the expected 50 years. Marketing activities must address the *educational needs* of the decision maker. The greatest opportunity for timber bridges appears to exist in the Midwest and Northeast. In these areas, timber is currently perceived higher in performance and attribute ratings; there is a high level of local control of rural bridges; and decay is slower than in other regions of the United States.

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Table 1. Mean Performance Scores by Material Type, Decision-Making Group and Geographic Region

Decision-Making Group (Mean Response)						
	Overall Response[1]	Local Officials	State DOT	Private Consultant	TBIP[2]	P-Value Univariate "F-Test"
Prestressed Concrete	5.79	5.78	5.80	5.84	5.51	.45
Steel	4.87	4.83	4.91	4.92	4.51	.53
Timber	3.70	3.99	3.28	3.73	4.41	.00
Reinforced Concrete	5.41	5.52	5.44	5.35	5.10	.73
Multivariate Hotellings Test P-Value = .00						
Geographic Region						
	Northwest	South	Mid-Atlantic	Northeast	Midwest	P-Value Univariate "F-Test"
Prestressed Concrete	6.00	6.06	5.86	5.50	5.56	.03
Steel	4.72	4.99	5.04	4.95	4.78	.02
Timber	3.80	3.32	3.17	4.01	3.99	.00
Reinforced Concrete	5.35	5.89	5.37	5.19	5.26	.01
Multivariate Hotellings Test P-Value = .00						

Multivariate Analysis of Variance (MANOVA) Decision-Making Level by Geographic Region	**P-Value Multi-variate "F-Test"**
Prestressed Concrete	.02
Steel	.04
Timber	.34
Reinforced Concrete	.00
Multivariate Hotellings Test P-Value = .00	

1: Scale 1 (below average) to 7 (above average), average = 4
2: Timber Bridge Initiative Participants

Table 2. Attribute Ratings by Decision Group

Attribute	Decision Group (Mean Response)					
Low Maintenance	Over-all[1]	Local	State	Private	TBIP	P-Value[2]
Prestressed Concrete	5.87	5.84	5.97	5.85	5.53	.14
Steel	4.19	4.40	4.21	4.05	3.87	.03
Timber	3.71	3.89	3.55	3.65	4.18	.03
Reinforced Concrete	5.46	5.64	5.51	5.29	5.24	.02
Pleasing Aesthetics						
Prestressed Concrete	5.10	5.14	5.14	5.12	4.38	.98
Steel	4.87	4.55	5.04	5.00	4.41	.00
Timber	4.92	5.16	4.68	4.91	5.35	.00
Reinforced Concrete	5.05	5.04	5.04	5.19	4.64	.49
Environmentally Safe						
Prestressed Concrete	5.71	5.72	5.87	5.60	5.35	.02
Steel	4.63	4.81	4.47	4.42	4.60	.03
Timber	4.65	4.73	4.56	4.72	4.68	.33
Reinforced Concrete	5.52	5.54	5.62	5.46	5.19	.23
Low Cost						
Prestressed Concrete	5.18	4.72	5.44	5.26	4.86	.00
Steel	4.26	4.41	4.15	4.33	4.12	.08
Timber	4.41	4.88	3.94	4.62	4.53	.00
Reinforced Concrete	4.89	4.69	5.11	4.79	4.74	.00

1: Scale 1 (below average) to 7 (above average), average = 4
2: Values do not include TBIPs in the MANOVA comparisons.

Table 2. (cont.) Attribute Ratings by Decision Group

Attribute	Decision Group (Mean Response)					
Low Maintenance	Overall[1]	Local	State	Private	TBIP	P-Value[2]
Prestressed Concrete	5.19	5.06	5.44	5.06	4.70	.00
Steel	4.89	4.91	4.87	5.05	4.35	.45
Timber	4.64	4.87	4.34	4.81	4.49	.00
Reinforced Concrete	5.20	4.94	5.45	5.15	4.89	.00
Easy to Construct						
Prestressed Concrete	5.54	5.37	5.72	5.52	5.12	.01
Steel	4.89	4.80	4.88	5.10	4.44	.01
Timber	5.01	5.29	4.81	4.98	5.20	.00
Reinforced Concrete	4.70	4.61	4.91	4.54	4.42	.02
Long Life						
Prestressed Concrete	5.86	5.95	5.99	5.70	5.48	.00
Steel	5.02	4.92	5.14	5.03	4.66	.09
Timber	3.80	4.04	3.55	3.78	4.40	.13
Reinforced Concrete	5.58	5.78	5.65	5.44	5.16	.01
High Strength						
Prestressed Concrete	5.91	5.96	5.96	5.87	5.66	.26
Steel	5.88	5.66	5.98	5.92	5.73	.00
Timber	3.72	4.19	3.47	3.51	4.25	.00
Reinforced Concrete	5.34	5.71	5.31	5.13	5.17	.00

1: Scale 1 (below average) to 7 (above average), average = 4
2: Values do not include TBIPs in the MANOVA comparisons.

Table 3. Factor Loadings for Materials on Eight Selected Attributes

Material	Prestressed Concrete		Reinforced Concrete		Timber		Steel	
	Factor Loading		Factor Loading		Factor Loading		Factor Loading	
Factor 1	1	2	1	2	1	2	1	2
Cronbach's Alpha	.781		.772		.758		.759	
"Physical Characteristics"								
Long Life	.83	.20	.71	.32	.83	.16	.77	.26
High Strength	.81	.12	.73	.17	.74	.20	.70	.11
Low Maintenance	.70	.19	.67	.29	.77	.13	.69	.20
Environmental Safety	.64	.31	.69	.14	.52	.15	.61	.31
Pleasing Aesthetics	.51	.32	.66	.11	.65	-.08	.66	.14
Factor 2								
Cronbach's Alpha		.795		.796		.691		.716
"Design Decision Criteria"								
Easy to Design	.22	.82	.23	.79	.16	.79	.19	.81
Low Cost	.15	.81	.17	.81	.12	.70	.16	.73
Easy to Construct	.32	.77	.25	.82	.06	.83	.29	.73

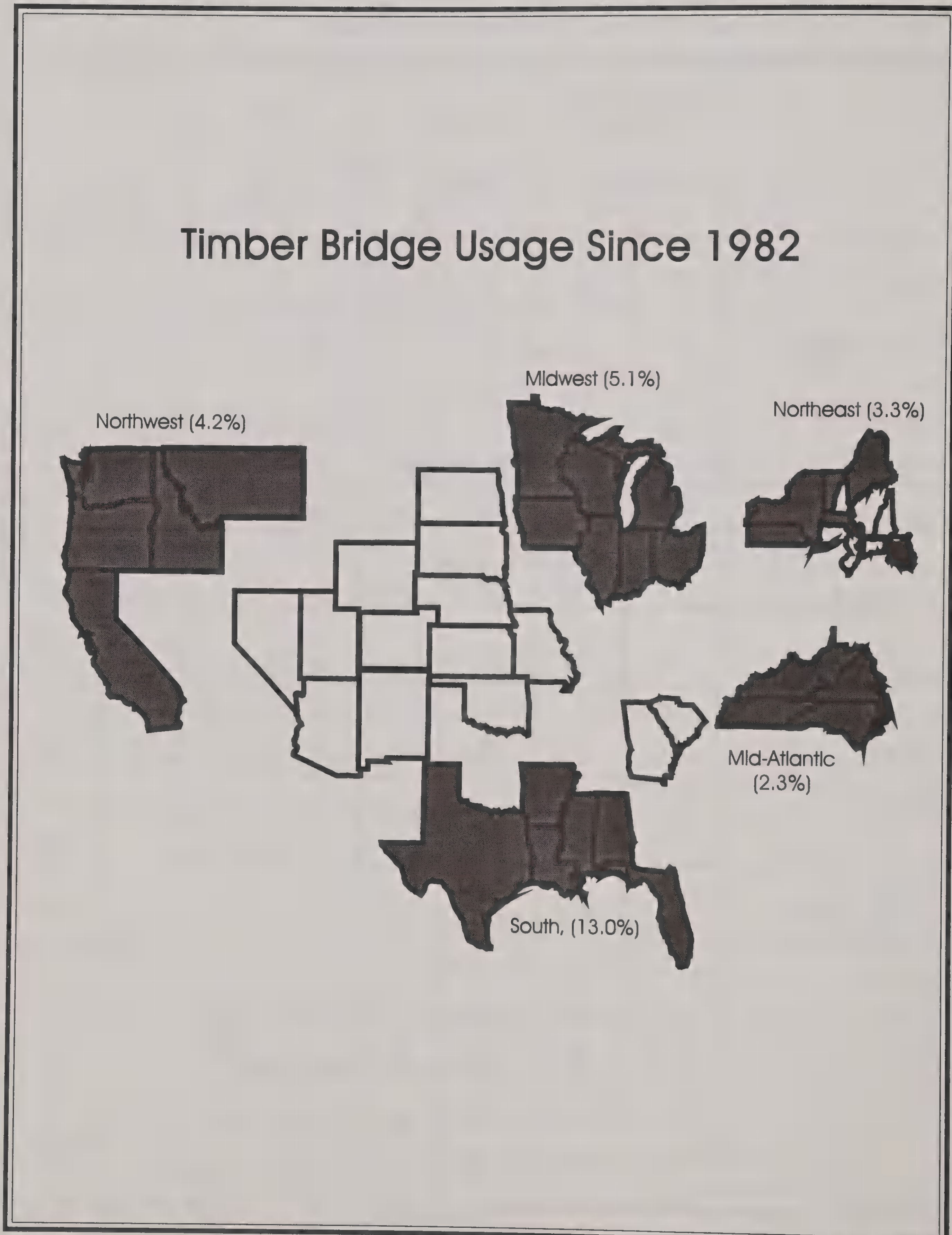

Figure 1. Timber Bridge Use by Geographic Region Since 1982

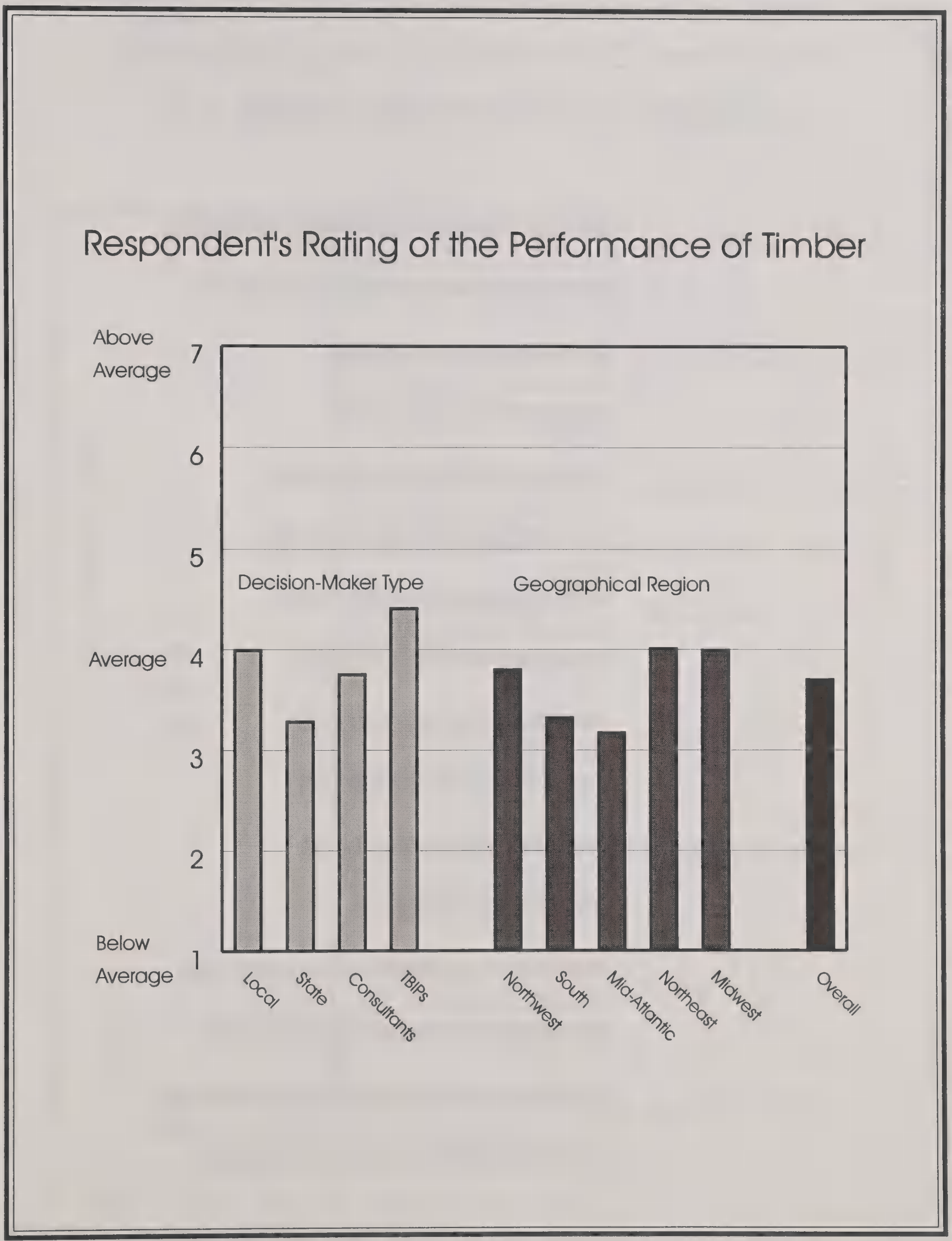

Figure 2. Perceived Overall Performance Rating of Timber as a Bridge Material

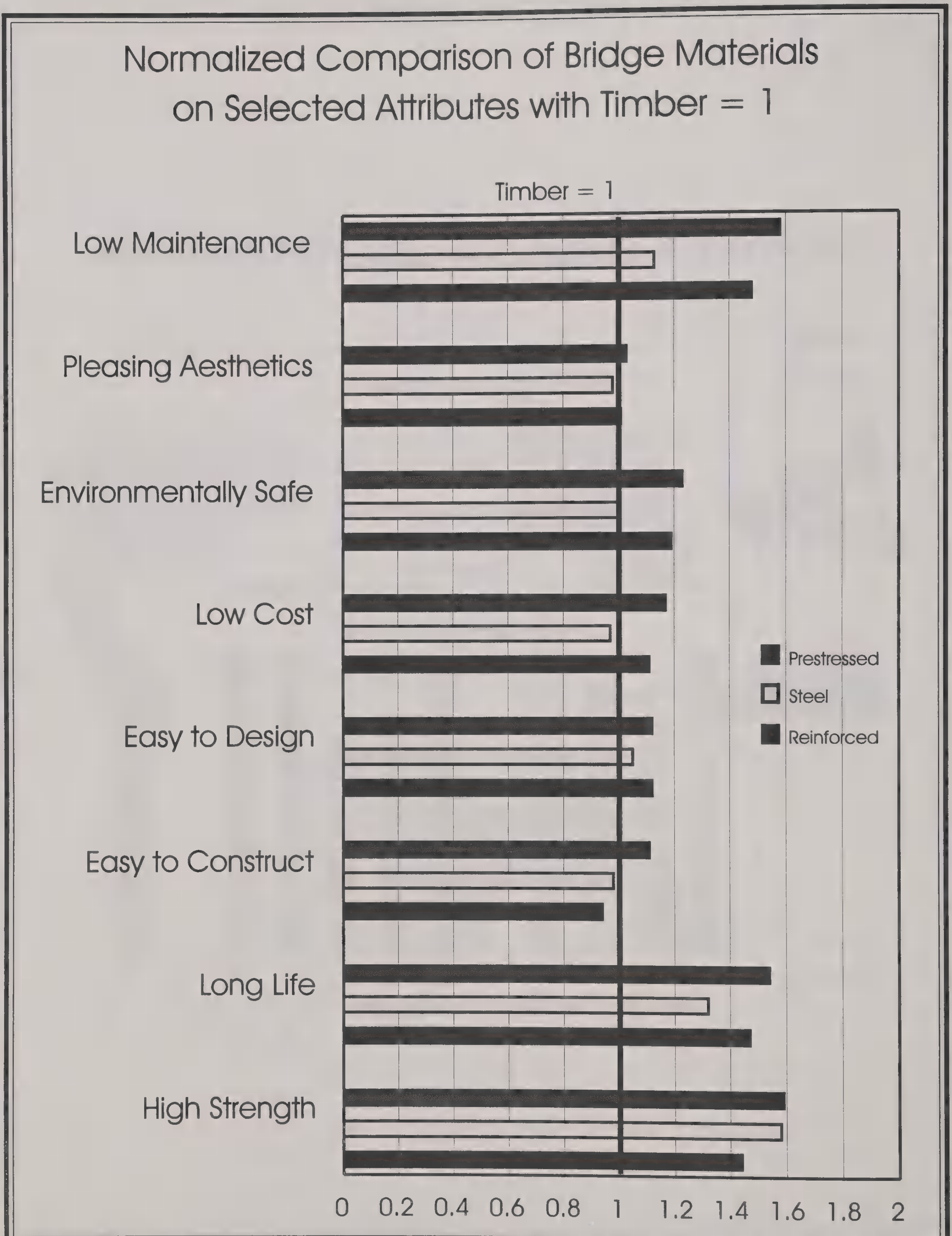

Figure 3. Material Attribute Ratings Normalized to Timber = 1

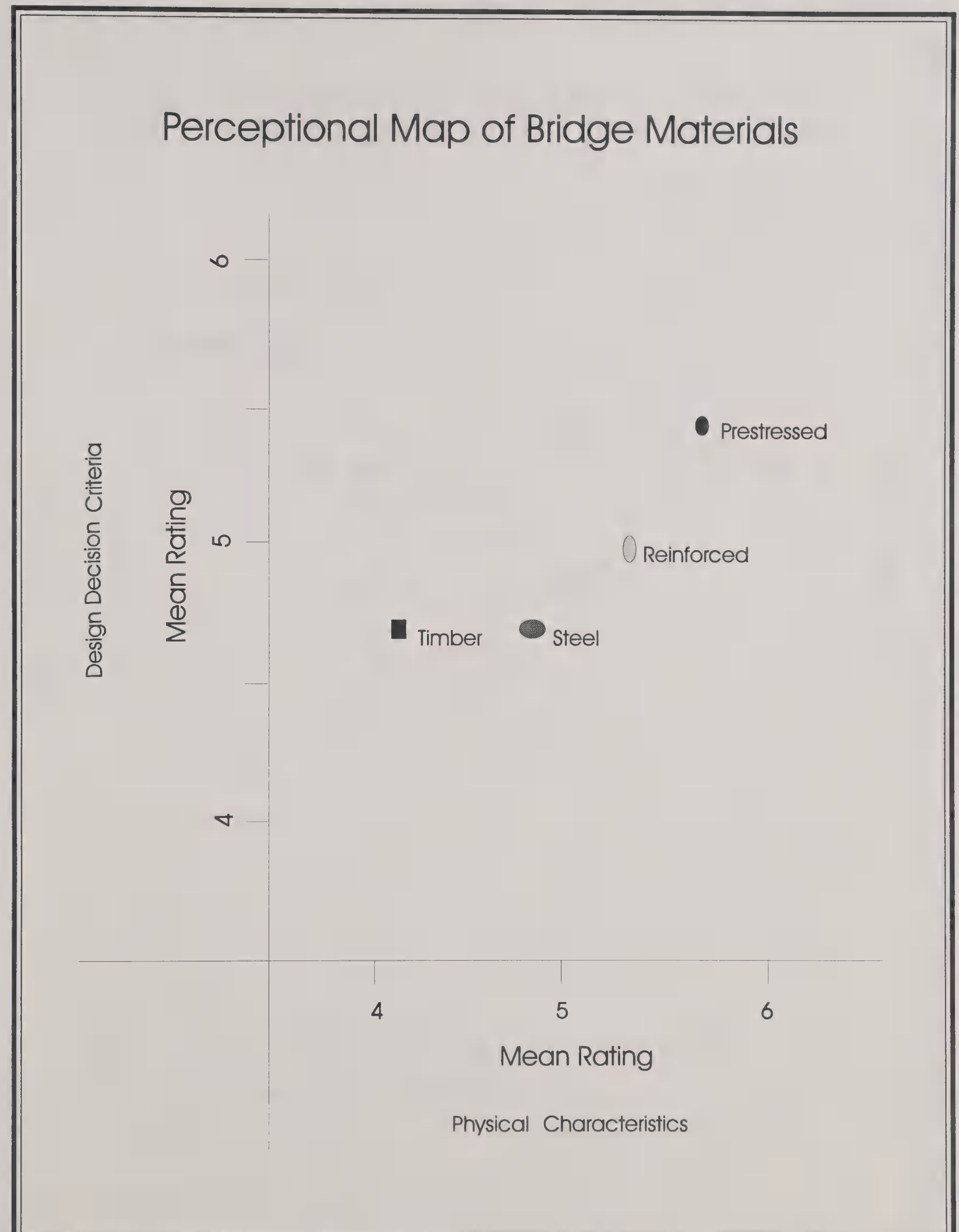

Figure 4. Perceptions of Bridge Materials' Attributes Reduced to Two Dimensions

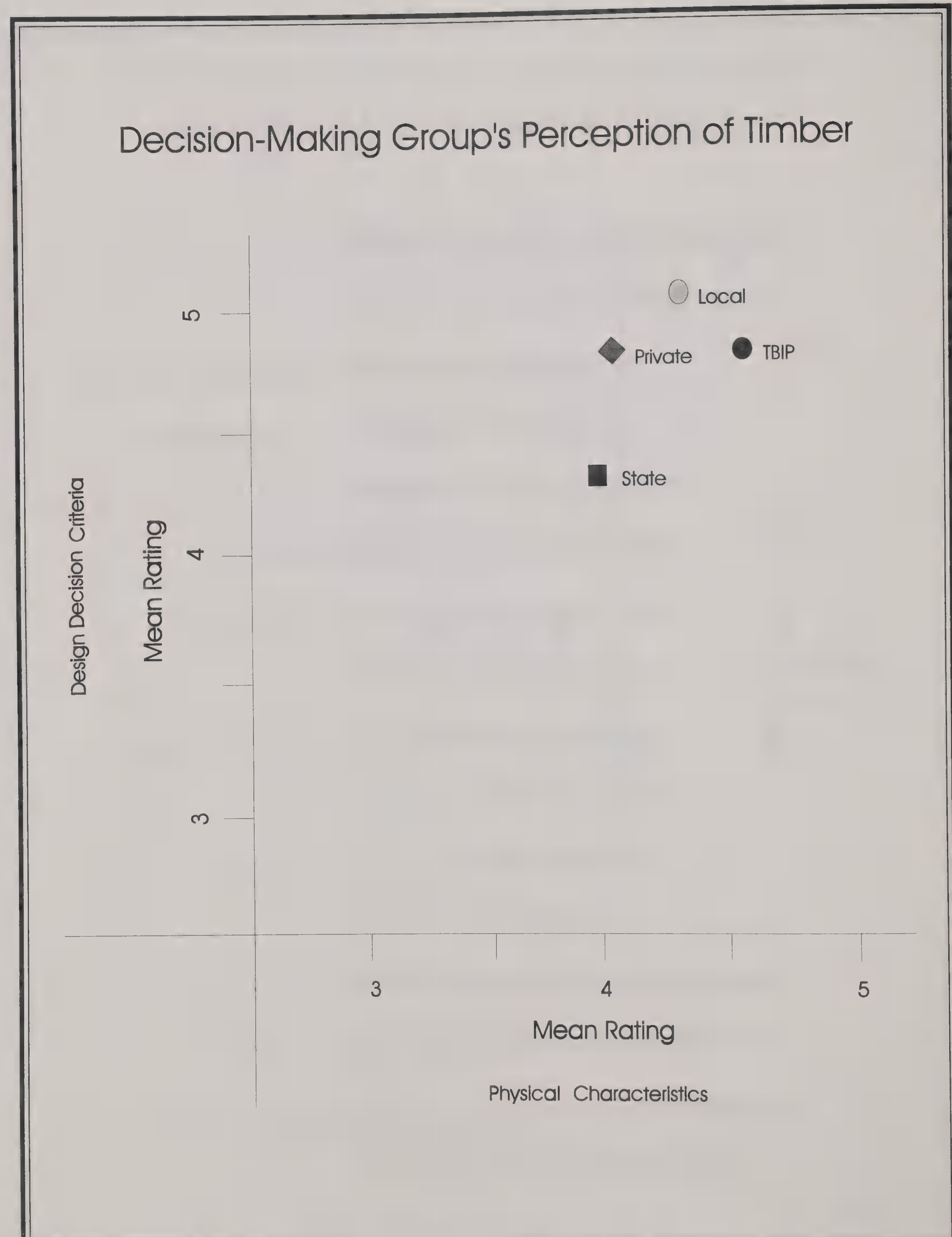

Figure 5. Perceptions of Timber as a Bridge Material by Decision-Maker Type

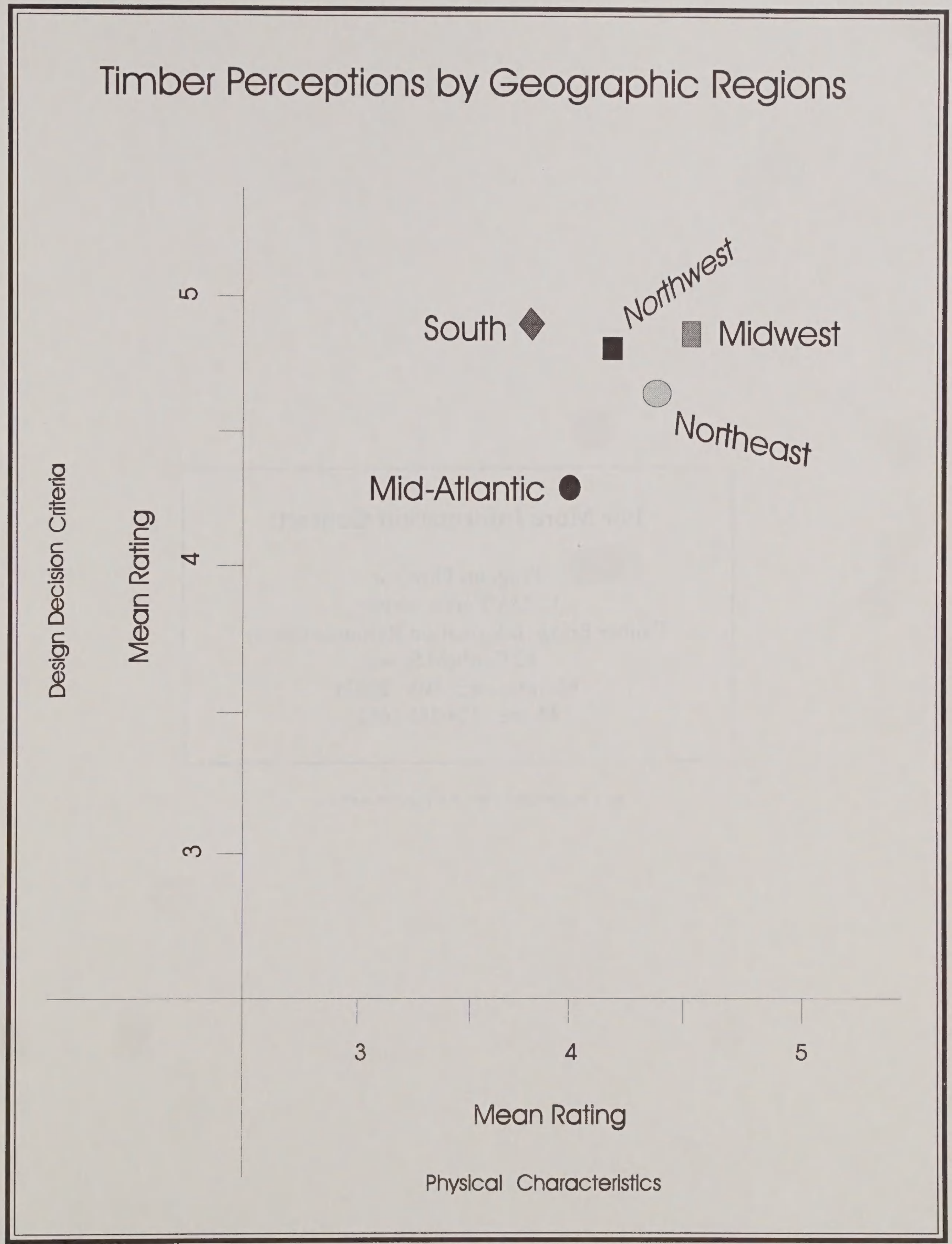

Figure 6. Perceptions of Timber as a Bridge Material by Geographic Region

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